Development of a 50-kW Fuel Processor for Stationary Fuel Cell Applications Using Revolutionary Materials for Absorption-Enhanced Natural Gas Reforming (New FY 2004 Project)

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Objectives

- Develop and test a fuel processor capable of producing a high hydrogen concentration (>98%) reformate containing inconsequential levels of carbon dioxide and carbon monoxide.
- Develop high durability CO_2 absorbents containing both high temperature water gas shift (WGS) and steam reforming catalysts.
- Perform process design, system efficiency, and cost estimate studies.
- Design, construct, and test a “stand alone” natural gas fed 50-kW fuel processor which will meet these performance targets: efficiency >85%, CO concentration <10 ppm, H_2S concentration <50 ppb, system life >40,000 hours.

Technical Barriers

This project addresses the following technical barriers from the Fuel Cells section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year R,D&D Plan:

- I. Fuel Processor Start-Up Time
- J. Durability
- K. Emissions/Environmental Issues
- L. Hydrogen Purification/Carbon Monoxide Cleanup
- N. Cost

Approach

ChevronTexaco will develop a natural gas fueled 50-kW fuel processor capable of producing a high hydrogen concentration (>98%) reformate containing inconsequential levels of carbon dioxide and carbon monoxide. This capability will be achieved using a new catalyst powder manufacturing technique which promises to breathe new life into an old fuel processing concept, adsorption-enhanced reforming (AER). ChevronTexaco will use a unique spray-based powder manufacturing approach to develop and produce powders that have been specifically designed for absorption-enhanced reforming using logical materials design concepts. The spray-based powder manufacturing approach allows the creation of materials with unique microstructures and compositions that cannot be achieved by competing powder manufacturing approaches. Initial results indicate that this approach may lead to a major breakthrough in the development of high capacity, highly reversible CaO-based CO_2 absorbents. The combination of Cabot Superior Micropowders' (CSMP) unique powder manufacturing capabilities, ChevronTexaco's refining catalyst experience, and Texaco Energy System LLC's (TES) natural gas reforming/fuel cell experience presents the opportunity for higher fuel cell power plant efficiencies, reduced capital costs, and long term environmental benefits.

The ChevronTexaco team will develop a single catalyst bed composed of high durability CO_2 absorbents, high temperature water gas shift catalysts and steam reforming catalysts. Process design, system efficiency, and cost estimate studies will be performed leading to the design, construction, and testing of a "stand alone" natural gas fed 50-kW fuel processor. This approach is in contrast to the high capital and operating costs associated with pressure swing adsorption or membrane separation.

The major benefits of this approach are the reduced cost combined with an increase in performance and reliability of the whole fuel cell system. The production of a high purity hydrogen feed stream based on the reaction $CH_4 + 2H_2O + CaO \rightarrow 4H_2 + CaCO_3$ leads not only to a lower cost, highly efficient fuel processor, but also reduces the cost (higher H_2 content = less precious metal in the membrane electrode assembly) and improves the durability of the fuel cell stack through reduction of CO (poison) and CO_2 (reverse WGS and acidity enhancer). The system will comprise two or more AER beds, some of which are recycled while one is used to reform the natural gas. In addition to the reactor, the system will contain heat exchangers, a methanation unit, a desulfurization unit and a tail gas oxidizer. We estimate this system will achieve at least 85% energy efficiency with less than 10 ppm CO and less than 50 ppb H_2S in the reformate and with durability of more than 40,000 hours. Our current estimate of the reactor volume is about 80 liters with three reactors required.

Past work has proven the concept, but commercialization has failed due to the poor durability of the carbon dioxide absorption material. Materials that were produced in a cooperative program between CSMP and ChevronTexaco researchers have shown the feasibility of greatly improved durability. The extrudates made with powders manufactured by CSMP's spray technology retain their original CO_2 absorption capacity and carbonation/de-carbonation kinetics through many cycles. Tests of the process in TES's automated small scale reactors confirm the ability of the process to produce >98% purity H_2 with inconsequential levels of CO_2 and CO.